Date of issue: December 2018

Deliverable ID: D 10.4

ENFAIT
ENABLING FUTURE ARRAYS IN TIDAL

DTOcean: Comparative with Design

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 745862.

Document History

DOCUMENTATION SHEET	
Project Acronym	EnFAIT
Project Title	Enabling Future Arrays in Tidal
Grant Agreement number	745862
Call identifier	H2020-LCE-2016-2017
Topic identifier	LCE-15-2016
Funding Scheme	Research and Innovation Programme
Project duration	60 months (July 2017 – June 2022)
Project Officer	Dana Dutianu (INEA)
Coordinator	Nova Innovation Ltd
Consortium partners	Nova Innovation, ELSA, SKF, University of Edinburgh, Mojo Maritime, Wood Group, HMK, RSK Environnement, ORE Catapult
Website	www.enfait.eu
Deliverable ID	D 10.4
Document title	DTOcean: Comparative with Design
Document reference	EnFAIT-EU-0043
Description	Report setting lessons learned from the application of DTOcean tools to the design of a real-world array.
WP number	WP 10
Related task	T 10.4
Lead Beneficiary	UOE
Author(s)	Tianna Bloise Thomaz Leonore Van Velzen
Contributor(s)	
Reviewer(s)	Gary Connor
Dissemination level	PUBLIC - This document in whole, or in part, may be used in general and public dissemination.
Document status	Final
Document version	1.0

REVISION HISTORY					
Version	**Status**	**Date of issue**	**Comment**	**Author(s)**	**Reviewer**
0.1	Draft	Nov-2018	Initial draft for review	Tianna Bloise Thomaz Leonore van Velzen	Tbc
0.2	Draft	03/12/2018	Feedback from Nova		Tom Wills
0.4	Draft	07/12/2018	Feedback from Wood, OREC and Nova		Tom Wills and Andy MacGillivray
1.0	Final	18/12/2018	Nova Innovation final review		Gary Connor

EnFAIT

Contents

Abbreviation and Definition ... 5

1 The Project ... 6

1.1 Introduction ... 6

2 DTOcean ... 8

2.1 DTOcean Feedback ... 9

3 Scenario Definition ... 10

3.1 Hydrodynamic, Electrical and Foundation modules ... 10

3.2 DTOcean Library ... 11

3.3 Environmental data ... 13

3.4 Others ... 14

4 Comparison with Design ... 15

4.1 Installation Module ... 16

4.2 Operation and Maintenance Module ... 23

4.3 Economic Assessment Module ... 25

4.4 Reliability Assessment Module ... 26

4.5 Environmental Assessment Module ... 28

5 Assessment of DTOcean capabilities ... 30

5.1 Areas for further investigation ... 31

6 Conclusion and future work ... 34

7 References ... 35

Appendix 1 ... 35

Abbreviation and Definition

ADCP	Acoustic Doppler Current Profilers
AEP	Annual Energy Production
CAPEX	Capital Expenditure
CSV	Construction Support Vessel
CLB	Cable Laying Barge
DTOcean	Design Tools for Ocean Energy Arrays
EnFAIT	Enabling Future Arrays in Tidal
EAM	Environment Assessment Module
EIA	Environmental Impact Assessment
EIS	Environmental Impact Score
FFPV	Fit-For-Purpose Vessel
GUI	Graphical User Interface
LCOE	Levelised Cost of Energy
MTTF	Mean Time To Failure
MWh	Megawatt Hour
O&M	Operation and Maintenance
OPEX	Operational Expenditure
RAM	Reliability Assessment Module
ROV	Remotely Operated Vehicle
WP	Work Package

1 The Project

1.1 Introduction

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme in January 2017 to demonstrate a grid-connected tidal energy array at a real-world tidal energy site, propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation – Enabling Future Arrays in Tidal (EnFAIT). This was in response to the call *LCE-15-2016: Scaling up in the ocean energy sector to arrays* to generate significant learning through demonstration of cost-effective tidal arrays.

One of the purposes of Work Package (WP) 10 of the EnFAIT project is to validate the DTOcean open source design tool. This document is produced to set out the lessons learned from application of DTOcean tools to design of real-world array. It is to be submitted to satisfy deliverable D10.4 of the EnFAIT project and to be made available for public dissemination.

This deliverable continues the work done in D10.3 DTOcean - Scenario Definition & Performance Metrics, which summarises the DTOcean first stage performance metrics, as well as all scenario information. The aim of these documents is to establish a baseline position of the capabilities of the DTOcean model for the EnFAIT project.

Please note that this document presents the preliminary outputs from the DTOcean suite of tools. It does not represent the design of the actual deployed array, nor is it proposed to change the existing array design. A comparison of DTOcean outputs with the actual array design choices made by Nova Innovation (Nova) is provided in this document, and summarised in section 5. The aim of this comparison is to provide a baseline assessment of DTOcean: insights gained from the design decisions made by Nova in deploying an existing array will be incorporated in the next versions of the DTOcean tool design.

The document is structured as follows:

- Section 1 describes the EnFAIT project's motivation and the objective of the present work.
- Section 2 introduces DTOcean, an open source tool used for the optimisation of array design used in this work, and the DTOceanPlus project to develop and demonstrate a suite of 2nd generation advanced design tools. This section also explains the relationship between D10.3 and D10.4.
- Section 3 defines the scenarios used in the analysis of the EnFAIT array. The data used for the simulations, regarding environmental time series, data from DTOcean Library, outputs from previous modules and other relevant information are presented.
- Section 4 compares the outputs provided by the tool against the existing array design.
- Section 5 summarizes the capabilities of DTOcean and suggests areas for future development of the tools, which will be valuable for the 2nd generation advanced design tools (DTOceanPlus).
- Section 6 offers conclusions and lessons learned from the application of DTOcean tools compared to the design of a real-world array. It summarises the differences observed between the numerical

model outputs and the existing array, areas for further investigation of the tool and explains the upcoming work of this WP, regarding the application of DTOcean.

2 DTOcean

DTOcean is a collaborative European project, which has produced an open source numerical tool for the optimisation of wave and tidal energy converter arrays. This section explains the main DTOcean structure regarding its modules, assessments and purpose. For further explanation of the design tool, the DTOcean Project can be referenced (DTOcean Project, n.d.).

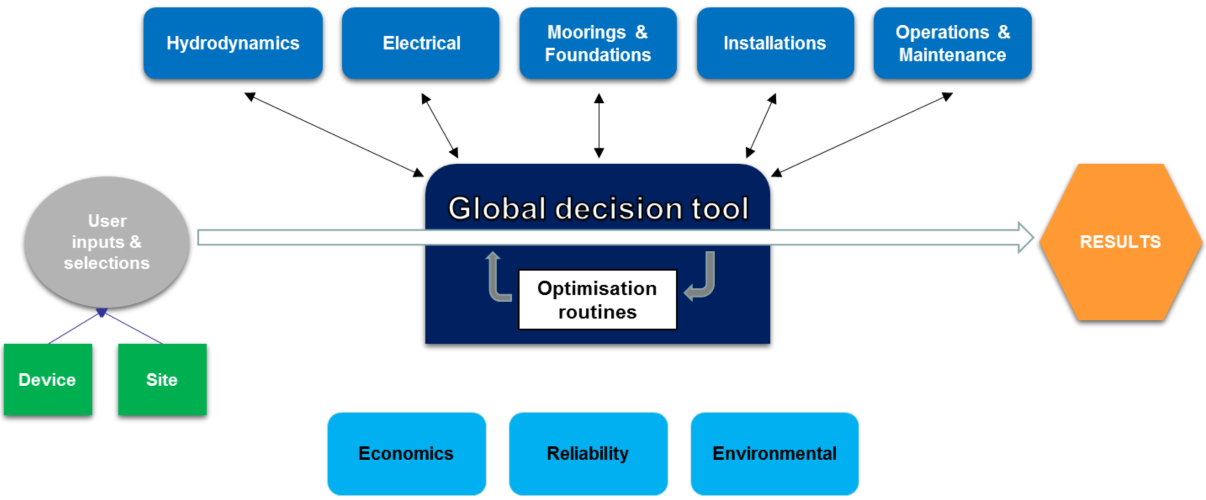

Figure 1 – DTOcean structure (DTOcean Project, n.d.).

DTOcean stands for Optimal Design Tools for Ocean Energy Arrays (DTOcean, 2016). DTOcean is modularised into five stages: hydrodynamics; electrical; moorings and foundations; installations; and operations and maintenance. The hydrodynamics module designs the layout of marine energy converters in a chosen region and calculates their power output. The electrical sub-systems module designs an electrical layout for the given converter locations and calculates the electrical energy exported to shore. The moorings and foundations module designs the foundations and moorings required to secure the converters at their given locations. The installation module designs the installation plan for the energy converters and the array components. Finally, the operations and maintenance module calculate the required maintenance actions and energy losses resulting from the operation of the converters over the lifetime of the array.

The five stages can be analysed from three thematic assessments: economics, reliability and environmental (see Figure 1). The economic assessment tool produces economic indicators for the design, in particular the Levelised Cost of Energy (LCOE). The reliability assessment evaluates the reliability of the foundation and electrical components during the array lifetime. Finally, the environmental impact assessment identifies the most sensitive receptors/stressors, which are combined into different environmental functions.

DTOceanPlus is an EU-funded project that will develop and demonstrate a suite of 2nd generation advanced design tools for the selection, development, and deployment of ocean energy systems. The 2nd generation suite of tools will build on the strong foundation of DTOcean (DTOcean Plus project, n.d.).

2.1 DTOcean Feedback

One of the purposes of Work Package (WP) 10 of the EnFAIT project is to validate the DTOcean open source tool. The work for D10.3 and D10.4 uses DTOcean in the first instance for array layout validation of the existing array of turbines. The data collected during the EnFAIT project will be used as suggestions to improve the 2nd generation of DTOcean tools (which will be covered in another EU-funded project – DTOceanPlus). Finally, when more confidence is gained within the numerical tools, DTOcean will be used to support the extended array design.

This report, D10.4, collects information to feedback into the DTOcean tool for improvement. It follows the work done in D10.3 where the first three modules and one thematic assessment were investigated, these being hydrodynamics; foundation and moorings; electrical; and economics, respectively. D10.4 will investigate the last two modules and two assessments, namely installation; operation and maintenance; reliability; and environment. In addition, the economic assessment is reassessed as the results of the last modules have a significant impact on the economic output.

The collection of feedback is done by comparing the existing array of the EnFAIT project with the DTOcean output. A qualitative classification of low, medium, high, or not applicable is attributed to different metrics or parameters, indicating the level of similarity between the existing array and DTOcean results. However, the focus of this report is not on this classification but on the suggestions for improvements to the DTOcean tool that follow the comparison between the real world and the modelling tool, summarized in section 5.1.

The feedback gathered during the EnFAIT project – which compares the design decisions of an existing array with DTOcean 1st generation tools – will be used in the DTOceanPlus project. This new version will consider the improvement suggestions as indicated in this document (D10.4) and in D10.3.

3 Scenario Definition

3.1 Hydrodynamic, Electrical and Foundation modules

As previously explained, the first three modules of DTOcean (Hydrodynamic, Electrical and Foundation) were assessed in D10.3. The following modules and assessments – Installation, O&M, Economics, Reliability and Environmental – are part of the work performed within this deliverable (D10.4). These last modules depend on the outputs obtained during the first three assessments. Therefore, the following sub-sections (3.1.1 and 3.1.2) will present a summary of the inputs assumed and outputs obtained when the first three modules of DTOcean were assessed. Further information is presented in D10.3.

3.1.1 Inputs

The input values as used for the previous deliverable D10.3 are presented in the Table 1. This information is implemented as base for this deliverable (D10.4). However, some changes have been made, incorporating changes and improvement made to the assumptions.

Table 1 – Non-exhaustive summary list of input parameters used for D10.3

Input	Information
Bathymetry	Bluemull Sound lease area
Lease area/Cable corridor	Bathymetry Resolution: 5m X 5m
Datum	1.37m below Ordnance Datum at Newlyn
Turbulence density	15%
Manning number	0.03523
Device rated power	100 kW, bi-directional
Network configuration	radial
Cables burial depth	0m
Minimum draft clearance	15m

3.1.2 Outputs

The results of the first modules are used as inputs for subsequent modules. Therefore, the location of turbines, type of foundation and the electrical system defined previously are characterizing the scenario for the current assessment.

When assessing the first three modules DTOcean suggests:

- Three devices placed in the lease area with enough space between them to maximize the energy production;
- A collection point placed offshore to connect the intra-array cables of each device with one export cable;
- The foundation type and size to be used for the devices, as well as, for the collection point.

Figure 2 shows the DTOcean design decisions for cable route and turbine location when considering project boundaries, see (EnFAIT D10.3, 2018) for details.

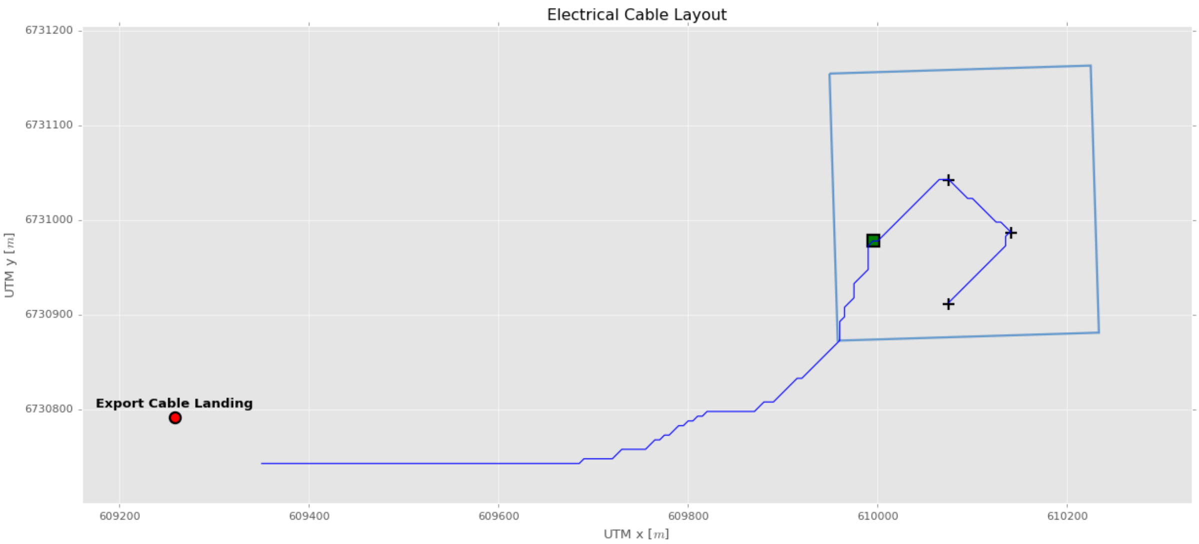

Figure 2 – DTOcean design decision, Hydrodynamic and Electrical modules (EnFAIT D10.3, 2018).

3.2 DTOcean Library

DTOcean has an internal library, consisting of a set of data, which the tool uses to calculate its results. The main library items are mentioned here: vessels, equipment, ports and failure rates.

3.2.1 Vessels

The DTOcean library contains fifty (50) vessels, which are divided in the following vessel classes:

- Heavy Lift Installation, such as a Construction Support Vessel (CSV);
- Offshore Service, such as a Tugboat;
- Offshore Support & Maintenance, such as a Multicat;
- Standby Cargo, such as a barge;
- Other, such as a Fit-For-Purpose Vessel (FFPV).

DTOcean defines physical limits to determine the potential vessels for a certain operation. These physical limits are related to, among others, weight and size. DTOcean also consider weather limits for each vessel. It is possible to edit the characteristics of the vessels in the library and include other options. The DTOcean library is populated with real vessels.

3.2.2 Equipment

The equipment types are categorized as follows:

- Remote operating vehicle (ROV) systems;
- Offshore Diving Teams;
- Cable Burial Tools;
- Subsea Excavating Tools;
- External protection equipment;
- Piling equipment.

DTOcean defines equipment day rates and other parameters such as equipment dimensions. It is also possible to edit the characteristics of the equipment in the library and include other options.

3.2.3 Ports

The DTOcean library contains twenty-five (25) ports, see Figure 3. The DTOcean database allows the user to modify this information by adding, deleting and editing the data. For the present work, Cullivoe and Belmont ports are included in the database.

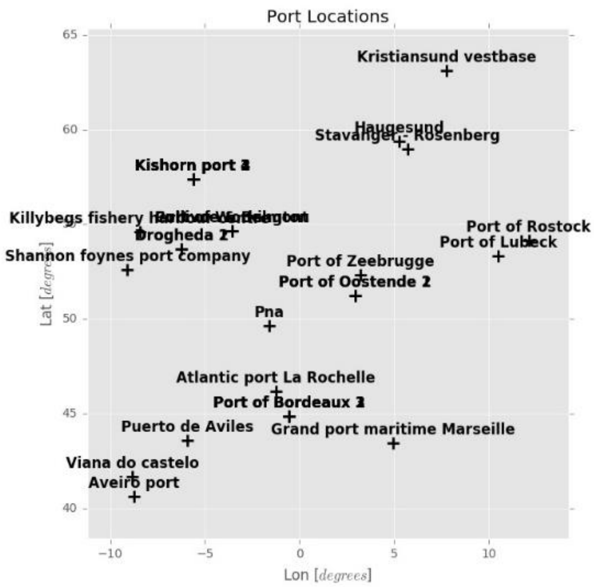

Figure 3 – DTOcean Library, Port Locations.

3.2.4 Failure rates

DTOcean suggests failure rates for different components of the ocean energy system, except for the device, which is defined by the user. Table 2 shows a couple of values defined in the DTOcean Library.

Table 2 – DTOcean Library, Failure Rates of components.

Components	Failure rate (failures per 10^6 hours)
Dry Mate Connector	15
Dynamic Cable	15
Static Cable	15
Transformers	0.5
Wet Mate Connector	15
Foundation Drag Anchor	1.187214612
Foundation Pile	0.011415525

3.3 Environmental data

The environmental data has been obtained from the information provided by EnFAIT project deliverable D10.2 – Bluemull Sound Site Resource Map (ref document: EnFAIT-EU-0021). Three Acoustic Doppler Current Profilers (ADCPs) were installed in the Bluemull Sound to monitor flow conditions and help understand the site tidal resource.

This data is used in this analysis as an initial input to DTOcean. An example overview of the tidal current, wave and wind speed time series at Bluemull Sound is plotted in Figure 4.

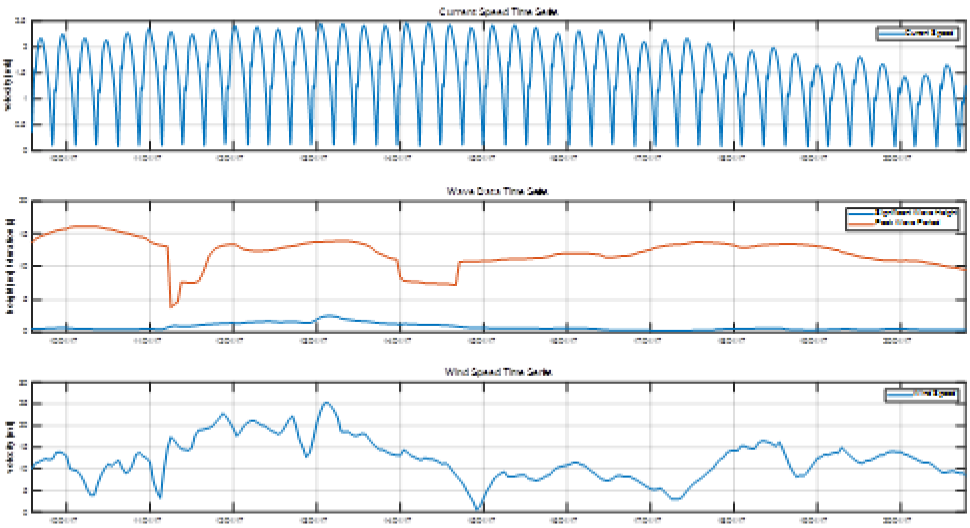

Figure 4 – Environmental data, Time Series

3.4 Others

Other relevant aspects of the array considered by DTOcean are summarised in the following list:

- Discount rate: 8%
- Project lifetime: 20 years
- Safety factors: 1.0 (as an initial approach)
- Project start date: 1st of June 2020

4 Comparison with Design

In order to establish the initial metrics for future comparisons and benchmark the performance of the DTOcean tool, a real case study with three turbines was analysed.

Each module of DTOcean is evaluated in this section to understand the tool and establish confidence levels with its choices. For each choice made by DTOcean, a comparison with the three turbines deployed by Nova in the Bluemull Sound is carried out. At the end of this deliverable document, a full comparison table is provided showing how the DTOcean suggestions align with the existing array. The qualitative classifications used for this comparison exercise are shown in Table 3. A colour code and a corresponding letter define the classification, which is divided into four categories, as follows:

- High similarity (**H**) **Green** : DTOcean outputs are similar to those of the existing array;
- Medium similarity (**M**) **Yellow** : some similarity between DTOcean outputs and existing array;
- Low similarity (**L**) **Red** : different results between DTOcean and existing array;
- Not Applicable (**N/A**) **Grey** : DTOcean outputs cannot be compared yet with existing array.

Table 3 – Classification criteria

Comparison between DTOcean and existing array	Classification
High similarity	H
Medium similarity	M
Low similarity	L
Not Applicable	N/A

Where applicable, the values have been normalised by those of the existing array. Therefore, in the tables in this report the existing array is considered as 100%, with the DTOcean results being presented as a proportional percentage of the existing array.

Comments and suggestions for future development of DTOcean are offered where appropriate. These recommendations are presented in boxes.

4.1 Installation Module

The installation module in the DTOcean tool aims to find the lowest cost installation process for the complete system as determined by the previous modules, namely hydrodynamics; electrical; and mooring & foundations. The output of the installation is given in five installation procedures, being installation of driven piles/foundations; installation collection point; installation of static export cables; installation of static array cables; and installation of devices. For the existing array, the collection point and static array cables are not taken into account, as there is not a collection point: each turbine has its own cable directly to shore. This was discussed in the electrical module section of deliverable D10.3.

The following sections provide a further comparison between the installation process as an output of DTOcean and that of the existing array.

4.1.1 Port selection comparison

Within the installation module, one of the functions is the selection of the base installation port, based on the potential of handling the largest required material, followed by the selection of the port nearest to the lease area. DTOcean will only provide one port from which all activities will take place.

Table 4 – Port selection

Item	Numerical Model (DTOcean)	Existing array	Classification
Port selection	Cullivoe	Cullivoe & Belmont	M

As can be seen in Table 4, the existing array makes use of two ports, as the lease area is strategically located between two ports. Due to the DTOcean allowing only one port selection, comparison between DTOcean and the existing array is classified as medium level of similarity.

Recommendation 1: Remove limitation on number of ports that can be selected

Port selection: DTOcean allows a selection of one port only. However, the design of the existing array indicates the selection of more than one port. For further versions of the tool, it is suggested that there be no limitation on the number of ports that can be selected.

4.1.2 Vessels selection comparison

The DTOcean tool database has a suite of vessel types. The logistics functions include the generation of vessel combinations needed to perform the logistic phases mentioned above. The internal DTOcean functions determine that most operations need multiple vessels, such as a Construction Support Vessel (CSV), a Cable Laying Barge (CLB) and the Multicat. Table 5 provides an overview of the combinations of selected vessels to install the foundations, export cable and devices.

Table 5 – Vessel selection

Item	Numerical Model (DTOcean)	Existing array	Classification
Vessel selection – foundations	One (CSV)	One (Multicat)	M
Vessel selection – static export cables	Multiple (CLB, Tugboat, Multicat)	One (Multicat)	L
Vessel selection – device installation	Multiple (CSV and Multicat)	One (Multicat)	L

The existing array was installed with one Multicat vessel, whereas DTOcean gives combinations of multiple vessels for the installation of cables and devices. Therefore, there is a low degree of similarity between the numerical model and existing practice on the array. The foundation vessel selection is classified as medium level of similarity because even though only one vessel is selected, the vessel type is not compatible with the existing array choice: Nova used a lower cost Multicat, rather than an Offshore Support Vessel.

A selection of multiple vessels may be more realistic for a larger array, however this will depend on the weight and geometry of the components, the extent to which equipment has been modularised and other factors defining the operational requirements (i.e. multi-stage installation) should be considered in the vessel selection. Ideally, DTOcean should be able to propose the most appropriate vessel for the specific operations that are being considered.

Recommendation 2: Improve the vessel selection function to make more informed decisions

Vessel selection - internal functions: The internal function of DTOcean that considers the selection of vessels should be revised to make more informed proposals.

The numerical tools could provide the user with an option to define the vessel as inputs, with flags to specify if the selection is a feasible or cost effective design choice.

Recommendation 3: Permit vessels to be manually selected

Vessel selection – as input: DTOcean does not provide an option for the user to select a vessel as input. The selection of vessels is an output of the tool. For further versions of the tool, it is suggested that vessel selection could be treated as either an input or output.

Finally, the selection of vessels is defined in the code, which is not a direct output for the user.

Recommendation 4: Include vessel selection on the Graphical User Interface

Vessel selection – GUI: The vessel selection is not provided as a result in the GUI, this can only be found if the user explores the code. For future versions of DTOcean, it is suggested that the vessels selected for each activity are identified in the GUI.

4.1.3 Equipment selection comparison

The numerical tool identifies a number of different items of equipment to assist the installation of the devices, foundations and cables. For the existing array, only one piece of large equipment in addition to the Multicat vessel is necessary because Nova's double armoured cables are laid directly on the seabed from the same vessel that installs the devices and their foundations. These cables have been proven to be stable in this condition: no ROV, cable burial equipment or drilling rig is required. Table 6 identifies the equipment selected on DTOcean and the one used for the existing array.

Table 6 – Equipment selection

Item	Numerical Model (DTOcean)	Existing array	Classification

Equipment type selection	ROV, Cable burial, Drilling rigs	Cable reeler	L

For the existing array, offshore subsea activities require the use of other small items, which are not taken into account in DTOcean. For the reasons outlined, the equipment type selection is classified with low level of similarity.

A different design choice made in previous modules (Hydrodynamic, Electrical and Foundation), will influence choices made for the marine operations. For example, the selection of cable burial equipment is due to the cables being buried as determined in the Electrical module. As explained in D10.3, there is no compatible choice for cable installation techniques of DTOcean compared to the technique used to deploy the cables of the existing array. Therefore, DTOcean assumes that the cables would be buried and that's the reason why cable burial equipment is selected.

As well as for the selection of vessel, the selection of equipment is defined along the code. Again, this is not a clear identification for the user.

Recommendation 5: Update library to include additional + smaller equipment items

Equipment selection – DTOcean Library: Update the library to include (smaller) equipment items. An example would be to include the cable reeler, in order to represent projects where cables are laid directly on the seabed.

Recommendation 6: Include equipment selection on Graphical User Interface

Equipment selection - GUI: The equipment selection is not provided as a result in the GUI. For the improvement future versions of DTOcean, it is suggested that the equipment selected for each activity be identified in the GUI.

4.1.4 Main installation tasks comparison

The installation plan is based on Gantt chart rules. Comparing the order of execution of the installation of the existing array with the DTOcean plan shows that the order of the plan is broadly the same (install the foundations, then the cables, then the devices). Due to different choices in the previous modules, specifically the application of a collection point (or subsea hub) within DTOcean (as discussed in D10.3), there are some differences between the two plans. This is classified as having a medium level similarity.

Table 7 – Main Installation tasks

Item	Numerical Model (DTOcean)	Existing array	Classification
Main installation tasks	Foundation, Collection point, Cables, Device	Foundation, Cable, Device	M

Recommendation 7: Permit activities to run concurrently when appropriate

Main installation tasks: Some onshore preparation activities and offshore activities could run concurrently, however, DTOcean does not consider this. For example, the onshore crew could start the preparation of cables after completing the preparation of foundations.

Recommendation 8: Allow for turbines to have individual cables (where appropriate)

Main installation tasks: DTOcean assumes that all arrays will have a collection point (or subsea hub), but on some sites it may make sense for turbines to have individual cables to shore. This was discussed in the electrical module section in report D10.3.

4.1.5 Installation Plan (Time) comparison

DTOcean calculates the time duration of all the logistic phases as the sum of the preparation time (time at port), departure delay (waiting for weather window), transit time, waiting time and operation time (time at sea).

The following tables present the level of similarity among the times defined on DTOcean and the existing array.

4.1.5.1 Preparation time

The preparation time is the time spent on mobilisation of vessels, assembly of components and preparation and loading of vessels. An example of preparation time within DTOcean is the time to load cables on a turntable.

Table 8 – Installation plan – preparation time

Item	Components	Numerical Model (DTOcean)	Existing array	Classification
Preparation time	Foundation	40%	100%	M
	Cables	665%	100%	L
	Devices	165%	100%	M

Table 8 demonstrates a medium level of similarity between the preparation time of devices and foundation on the numerical model and the existing array. As previously mentioned, the existing array makes use of two ports, which is not possible within DTOcean. Evidently, the use of two ports has an impact on the installation routine of the substructure, as it is assembled in a multi-stage process. This results in differences in the different time items, such as the preparation and transit time.

The preparation time of cables is classified as low level of similarity. DTOcean considers that the cable is loaded onto a reel at port and requires an installation rate as input for loading the cables onshore. However, for the existing array the cables are already loaded onto individual reels when received, negating the need for loading time.

Recommendation 9: Provide option for pre-loaded cables

Loading rate: DTOcean requires a cable loading rate (m/hour) to be considered. Real array experience suggests that future versions of DTOcean could also provide a second option where the cable is delivered on reels, negating the load rate.

The device preparation time considers many uncertainties. The granularity of DTOcean does not allow for an accurate representation of the preparation activities.

4.1.5.2 *Departure delay*

The departure delay is the time necessary to wait for an appropriate weather window. At that point, all the port activities are complete. The numerical tool indicates that this time is extremely sensitive to the start date of the project installation phase, as well as, to the weather limits.

Table 9 – Installation plan – departure delay

Item	Components	Numerical Model (DTOcean)	Existing array	Classification
Departure delay	Foundation	600%	100%	L
	Cables	700%	100%	L
	Devices	1800%	100%	L

As observed on Table 9, there is a low level of similarity between DTOcean design choices and the existing array. After investigating this discrepancy, it became clear that DTOcean's metocean analysis requires higher resolution time series data. Offshore operations on tidal energy sites depend predominantly on slack water periods where the tidal current is below a certain level (and the waves/wind/visibility are within required limits). To determine these slack water periods, a higher time resolution is required.

Recommendation 10: Ensure environmental data is of sufficiently high resolution to make meaningful assessments

Environmental data resolution: The input environmental data needs to be of sufficiently high resolution to make informed assessments of the likely sequence of marine operations.

These results will be reassessed when the environmental data with higher resolution is provided.

4.1.5.3 *Transit time*

Transit time is related to the distance from port to site, site to site and site to port.

Table 10 – Installation plan – transit time

Item	Components	Numerical Model (DTOcean)	Existing array	Classification
Transit time	Foundation	8%	100%	L
	Cables	100%	100%	H
	Devices	70%	100%	H

Comparing the DTOcean output with the existing array, the transit time has similarities for the cables and devices – this is to be expected, as transit distances and speeds were provided by Nova. However, the transit time for the foundation is significantly different. This can be attributed to the multi-stage process and use of two ports for the substructure with the existing array, as explained above (preparation time).

4.1.5.4 *Waiting time (at sea)*

The waiting time at sea shows a high level of similarity between DTOcean and the existing array for all the components considered.

Table 11 – Installation plan – waiting time

Item	Components	Numerical Model (DTOcean)	Existing array	Classification
Waiting time	Foundation	100%	100%	H
	Cables	100%	100%	H
	Devices	100%	100%	H

4.1.5.5 Operation time

The operation time is the time spent carrying out operations offshore. An example of operation time is the time to position the vessel on site or position the component and perform its connection.

Table 12 shows a low level of similarity between design choices of the numerical model and the existing array. The operation time considers many uncertainties. DTOcean does not have the granularity to represent operation activities accurately.

Table 12 – Installation plan – operation time

Item	Components	Numerical Model (DTOcean)	Existing array	Classification
Operation time	Foundation	240%	100%	L
	Cables	680%	100%	L
	Devices	400%	100%	L

4.1.5.6 Others

After the operation time, DTOcean does not take into account the demobilisation time.

Recommendation 11: Demobilisation time to be included

Demobilisation time: DTOcean does not take the demobilisation time into account. This time and associated costs should be considered for the improvement of the tools and accuracy of results.

DTOcean also considers that installation activities happen during 24 hours. The existing array experience indicates that developers could limit offshore activities to the daylight hours, due to safety reasons.

Recommendation 12: Limit night operations

Activities during daylight: Future versions of DTOcean should consider, as an option for the installation module, the limitation of the daylight-only activities. Night operations are often avoided due to safety reasons.

4.1.6 Cost comparison

The cost of installation is based on vessel cost (see Table 13), equipment cost (see Table 14), port costs and contingency. The present work disregards port and contingency costs.

4.1.6.1 Vessel cost

The total cost of vessels considers the cost of vessels used for the installation of each component. As previously explained, Nova use one Multicat vessel for all operations, whereas DTOcean assumes/requires multiple vessel types. This results in a medium classification of the vessel cost.

Table 13 – Cost of selected vessel(s) for installation

Item	Existing array	Classification
Vessel cost	Confidential	M

DTOcean results show that the highest percentage of vessel costs come from the installation of cables. The type of vessel required for the cable installation – CLB (Cable Laying Barge) – is more expensive than the vessels used by Nova, e.g. Multicat.

During the assessment of the installation module, Nova suggested that the vessel costs on DTOcean Library should be updated.

Recommendation 13: Expand range of vessels in DTOcean library and update costs

DTOcean Library: Update vessel costs in the library and expand the range of vessels. E.g. CSV vessels could be up to 10 times more expensive than the options presented.

4.1.6.2 Equipment cost

The total cost of equipment considers the cost of equipment used for the installation of each component. As previously explained, Nova use one piece of significant equipment for cable laying operations, whereas DTOcean assumes/requires certain equipment types. It results in a medium classification for the cost of equipment.

Table 14 – Cost of selected equipment for installation

Item	Existing array	Classification
Equipment cost	Confidential	M

The only significant offshore equipment that Nova need to hire is a cable reeler. For this assessment the other DTOcean equipment types were set to zero.

4.1.6.3 Others

Recommendation 14: Incorporate seasonal activities

Winter operations: Future versions of DTOcean should consider that activities during winter time can take longer and therefore be more expensive, due to the reduced amount of suitable weather windows and daylight that are available.

Recommendation 15: Decommissioning

Decommissioning stage: Decommissioning is not taken into account in DTOcean, this should be added within future versions of DTOcean.

4.2 Operation and Maintenance Module

The Operation & Maintenance (O&M) module aims to minimise the impact of O&M on LCOE. The O&M of the complete lifetime of the array is calculated. Maintenance is considered as either corrective or preventive. The former is a reaction to unexpected failures, whereas the latter can again be subdivided into either Condition-based or Calendar-based preventive maintenance. Condition-based maintenance is activated based on monitoring processes. Calendar-based maintenance is performed on a regular basis. These strategies can be activated or deactivated to form different combinations. To simulate real-world maintenance, in this report all of the above-mentioned procedures are activated, leading to a combination of replacement, inspection and on-site maintenance activities.

Evidently, the results, such as the OPEX and availability, are highly dependent on the selected maintenance strategies. Investigating the activation of different maintenance strategies showed significant differences in results between different combinations.

The following sections discuss the DTOcean O&M results compared to the existing array O&M estimates. It should be noted that there are many uncertainties in the results based on the relatively low experience in operation and maintenance in the existing array. In addition, due to the significant difference in results with altering scenarios, meaning different activated maintenance strategies, the ability to make meaningful comparisons between the existing array and the DTOcean output is limited. This should be taken into account when going through the comparison below.

4.2.1 OPEX comparison

Operational Expenditure (OPEX) is based on the type of performed maintenance activities. OPEX is dependent on the labour, logistic and part cost of these activities. At this stage of the project, the DTOcean forecast is significantly higher than Nova estimates. More years of operational data are required to confirm.

Table 15 – OPEX

Item	Existing array	Classification
OPEX	Confidential	N/A

As mentioned, maintenance costs are highly dependent on the activated strategies. A comparison with the existing array should be made with high caution, due to the relatively low amount of real-life information available on early tidal arrays at this point. As a comparison of the OPEX between the DTOcean results and the existing array is not representative at his stage, this metric is classified as Not Applicable.

4.2.2 Availability (downtime) comparison

DTOcean estimates the downtime of the devices and the downtime of the array. The downtime of devices is related to the corrective and preventive activities duration. At present, the granularity of DTOcean does not deliver sufficient insight into the calculation of the downtime of the array or devices.

Recommendation 16: Develop the availability calculations and outputs

Availability: Future versions of DTOcean should include calculations of availability based on downtime of devices and provide more information about the calculation of the array availability.

Table 16 – Availability

Item	Classification
Downtime of devices	N/A
Downtime of the array	N/A

Table 16 shows the classification of these metrics when compared to the design of the existing array. At this stage of the project the DTOcean, more operational data is required to be able to make an appropriate comparison. Therefore, the classification of Not Applicable is applied.

4.2.3 Life time energy production comparison

DTOcean defines the annual energy production (AEP) of the device for each operational year. Table 17, shows a high classification between the numerical tool and the existing array, the latter is based on a theoretical AEP calculation. Therefore, this comparison is based on two theoretical calculations. A refined assessment can be made in the future, based on the operation time of the existing array.

Table 17 – Life time energy production

Item	Numerical Model (DTOcean)	Existing array	Classification
Life time energy production	100%	100%	H

4.2.4 Maintenance Plan comparison

The maintenance strategy compares the percentage of time and costs spent with different maintenance activities: corrective and preventive.

Table 18 – Maintenance plan

Item	Classification
Maintenance strategy	M
Activities order	L

Table 18 shows a medium level of similarity of the maintenance strategy between DTOcean outputs and the existing array. In both cases, the highest percentage of time and costs are associated with unexpected operations rather than planned ones. However, it is not clear how the order of the activities is defined in the DTOcean tool. This is the reason for the activity order being classified with a low level of similarity. This order will be further investigated when refined assessment of this module is performed.

Recommendation 17: Consider the downtime of replacement activity

Replacement activity - downtime: The Calendar Based maintenances disregard the downtime of replacement activities. Future versions of DTOcean to revise.

4.3 Economic Assessment Module

This report re-evaluates the economic assessment of DTOcean, which was initially evaluated in D10.3. This second assessment is carried out to explore the effect on the economic metrics due to the application of the other modules. In the previous deliverable, only one metric was obtained and compared with the existing array, namely Capital Expenditure (CAPEX).

4.3.1 Costs comparison

The total capital expenditure is provided as a metric of the economic assessment of DTOcean. As observed on Table 19 (which repeats the classifications of OPEX and AEP from Table 15 and Table 17), there is a medium degree of similarity between the CAPEX calculated within the numerical tools and the existing array. This is a reasonable estimate for a first-of-a-kind project. This will be further investigated when refined assessments of this module are performed.

Table 19 – Cost breakdown

Item	Classification
CAPEX	M
OPEX	N/A
AEP	H

4.3.2 LCOE comparison

For the LCOE calculations, the discounted values of CAPEX, OPEX and AEP are used. The DTOcean discounted values show a low degree of similarity with the estimates for the existing array. A sense-check by means of manual calculations (outside of DTOcean) suggests that the method used by DTOcean to calculate the discounted values are different of the standard methods used in the industry for the techno-economic assessment.

Because of this discrepancy of the discounted values as calculated by DTOcean as well as the assumptions and limitations of the model, DTOcean provides a high LCOE value when compared with estimates for the existing array. The manual calculated LCOE, based on the DTOcean CAPEX, OPEX and AEP values, is considered as a reasonable estimate for a first of a kind project. However, as the LCOE provided by DTOcean does not coincide with the estimates of the existing array, the LCOE is classified with a low similarity.

Table 20 – LCOE

Item	Classification
LCOE	L

Recommendation 18: Improve calculation methods for discounted CAPEX/OPEX/AEP values to obtain realistic values of LCOE

LCOE – discounted values: Future versions of DTOcean should revise methods for the calculation of the discounted values of CAPEX, OPEX and AEP, to obtain more realistic values of LCOE.

4.4 Reliability Assessment Module

One of the three assessment modules of DTOcean is the reliability of the system by considering the relations between the sub-systems and components. This is done by performing a simplified Failure Mode and Effects Analysis (FMEA), as well as different levels of reliability calculations to determine the sensitivity to failures. The reliability statistics output of this module, including the distribution of system reliability over the mission's lifetime; Mean Time to Failure (MTTF); and Risk Priority Numbers (RPNs), feeds into the O&M module.

At this stage of the project, the classification of levels of similarity is Not Applicable for the Reliability Assessment Module (RAM). There is a need to build a track record / experience with the existing array before the comparisons can be made accurately. A relevant comparison cannot be made at this point; therefore, all classifications in this module are Not Applicable.

4.4.1 Mean Time to Failure

The RAM provides the reliability and MTTF values for the following subsystems: export cables, substation, electrical subsystems per device, moorings and foundation subsystem per device.

Table 21 – MTTF

Item	Classification
System MTTF	N/A
Export cable MTTF	N/A
Moorings and Foundations Subsystems/device MTTF	N/A

The device reliability and MTTF is not assessed on the Reliability Module. The device comprises PTO, prime mover and support structure. The PTO reliability is one of the most important types of reliability, which has significant impact on the MTTF of the entire system. Therefore, it is suggested that the next generation of tools should consider device reliability on RAM.

Recommendation 19: Include device reliability

Reliability of the device: Future versions of DTOcean should include the reliability of the device on the RAM.

4.4.2 System reliability at mission time

The system reliability at mission time is another metric of RAM. A graph is provided for the system reliability during the project lifetime, see Figure 5.

Table 22 – System reliability at mission time

Item	Classification
System reliability at mission time	N/A

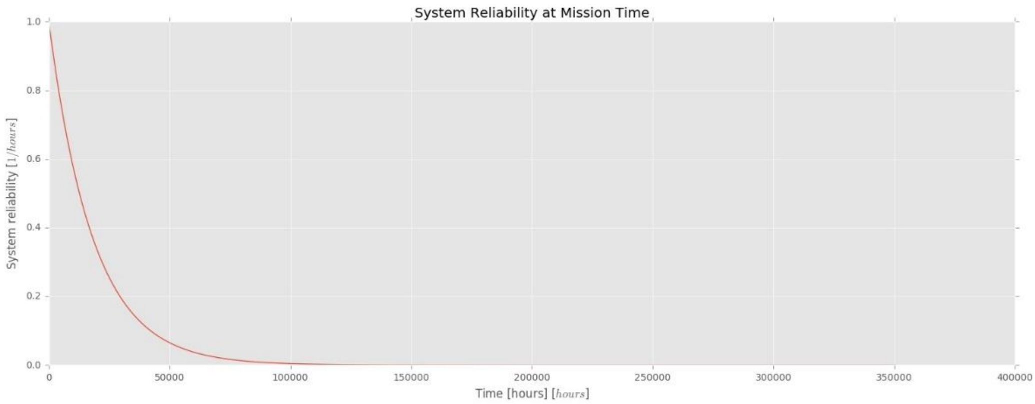

Figure 5 – System reliability at mission time, DTOcean

Although this comparison is Not Applicable, it should be noted that the graph behaviour of 'system reliability at mission time' is not as expected, for two reasons. First, every time the system is maintained, the system reliability should increase; and during the lifetime, the curve should decay again. It seems that DTOcean does not consider the effects of O&M in this graph. Secondly, the initial reliability is normally low, before the system starts to operate.

Recommendation 20: Include O&M in reliability of the system

System reliability at mission time: Future versions of DTOcean should include the effects of the O&M in the reliability of the system along its lifetime, as well as, correct initial considerations of the graph, to represent a realistic behaviour.

4.5 Environmental Assessment Module

The Environmental Impact Assessment (EIA) module will investigate the impact of the array implementation on the environment. This module accounts thirteen (13) functions related to positive and negative impacts. Each module of the numerical tools will allocate certain functions, which will be assessed in different levels of confidence, depending on the amount of detail provided. The Environment Assessment Module (EAM) will assess metrics based on a score system provided by each module (e.g. hydrodynamic, electrical), based on the technological choices.

The classification of levels of similarity is Not Applicable in this module. There is a need to build a track record / experience with the existing array before the comparisons can be made accurately. Besides, the environmental metrics are based on a score system, which makes the classification difficult.

4.5.1 Dictionary of the EIS (Environmental Impact Score)

The Environmental Impact Score (EIS) is one of the metrics of EIA. The EIS can range from +50 to -100, accounting for positive and negative impacts, respectively. Table 23 shows a list of environmental impacts assessed by DTOcean.

Table 23 – EIS, Environmental Impact Score

Item	Classification
Footprint	N/A
Collision risk	N/A
Collision risk vessel	N/A
Energy modification	N/A
Noise (underwater)	N/A
Electric fields	N/A
Magnetic fields	N/A
Chemical pollution	N/A
Turbidity	N/A
Temperature modification	N/A
Reef effect	N/A
Reserve effect	N/A
Resting place	N/A

At this stage, the environmental assessments of the existing array would be best suited for qualitative evaluations (high/medium/low.) More development is needed before quantitative scores (+50 to -100) can be applied with confidence.

Recommendation 21: Ensure confidence with the EIS method

Method of EAM: Future versions of DTOcean should assess the application of the EIS as the environmental assessment, to ensure confidence with this method based on quantitative scores.

4.5.2 Dictionary of Recommendation

EIA also provides a dictionary of recommendations to assist the user understand what is behind the score system. The recommendations are also available for each function of the modules. As mentioned above, a comparison would not provide a good insight at this point; therefore Table 24 shows a classification of Not Applicable.

Table 24 – Recommendations

Item	Classification
Recommendations	N/A

Although the comparisons are not straightforward during this assessment, it is interesting to note that some of the outputs of DTOcean EIA for the hydrodynamic module are considered to be broadly similar to the experience of the existing array, which are based on measurements taken on site.

It is also important to highlight that this version of the numerical tools is only providing results for the first module – Hydrodynamic.

Recommendation 22: Apply EAM to different stages

Functionality of EAM: Future versions of DTOcean should improve the environmental assessment module for the other stages, such as electrical, foundation, installation and O&M.

5 Assessment of DTOcean capabilities

This section assesses the current DTOcean capabilities, summarizing and qualitatively comparing the outputs of DTOcean with the actual array design, see Table 26. Table 25 is a reminder of the classification criteria, as presented earlier in Table 3. The code is divided into four categories, high similarity (H) – Green; medium similarity (M) – Yellow; low similarity (L) – Red; and Not Applicable (N/A) – Grey.

Table 25 – Classification criteria.

Comparison between DTOcean and existing array	Classification
High similarity	H
Medium similarity	M
Low similarity	L
Not Applicable	N/A

Table 26 – Summary of qualitative comparison between DTOcean and existing array.

Modules	Subcategories	Classification	Module Classification
Installation Metrics	Port selection	M	M
	Vessel selection – foundations	M	
	Vessel selection – static export cables	L	
	Vessel selection – device installation	L	
	Equipment type selection	L	
	Main installation tasks	M	
	Preparation time - Foundation	M	
	Preparation time - Cables	L	
	Preparation time - Devices	M	
	Departure delay - Foundation	L	
	Departure delay - Cables	L	
	Departure delay - Devices	L	
	Transit time - Foundation	L	
	Transit time - Cables	H	
	Transit time - Devices	H	
	Waiting time - Foundation	H	
	Waiting time - Cables	H	
	Waiting time - Devices	H	
	Operation time - Foundation	L	
	Operation time - Cables	L	
	Operation time - Devices	L	
	Vessel cost	M	
	Equipment cost	M	
Operation and Maintenance Metrics	OPEX	N/A	N/A
	Downtime of device	N/A	
	Downtime of the array	N/A	
	Life time energy production	H	
	Maintenance strategy	M	
	Activities order	L	

Economic Metrics	CAPEX	M	L
	LCOE	L	
Reliability Metrics	System MTTF	N/A	N/A
	Export cable MTTF	N/A	
	Foundations Subsystems/device MTTF	N/A	
Environmental Metrics	EIS (Environmental Impact Score)	N/A	N/A
	Recommendations	N/A	

The results presented on Table 26, suggests that the Installation module of DTOcean presents a medium level of similarity with the existing array. The discrepancies focus on the selection of port, equipment and vessels, as well as, on the installation plan (dates and time). The installation module is the one with more recommendations for the 2nd generation of the tools. This happens not only because this module contains more metrics than the others, which allows higher number of comparisons, but also due to the fact that the existing array has extensive experience with this stage – which results in a more detailed level of feedback on the tool.

The assessment of the O&M module suggests that the availability (downtime of the array), OPEX costs and activity order should be revised. However overall, this module presents reasonable resemblance to the design choices taken in the Bluemull Sound array. It is also stated that more years of operational data are required to confirm the assessment. Hence, this module gets an overall classification of Not Applicable. At a later stage, a more refined assessment of this module can be made.

The assessment of the economic module suggests that the discounted values of CAPEX, OPEX and AEP should be reassessed, as this influences the results of the LCOE directly.

Reliability and Environmental modules were classified as Not Applicable for comparison with the existing array. There is a need to build a track record / experience with the existing array before the comparisons can be made accurately. Besides, the environmental metrics are based on a score system, which makes the classification difficult. However, both modules were assessed and suggestions for their improvement were made.

5.1 Areas for further investigation

After comparing DTOcean with an existing array design, some areas for further investigation and improvement for the DTOcean numerical model are listed below:

1. Port selection: DTOcean allows a selection of one port only. However, the design of the existing array indicates the selection of more than one port. For further versions of the tool, it is suggested that there be no limitation on the number of ports that can be selected.

2. Vessel selection - internal functions: The internal function of DTOcean that considers the selection of vessels should be revised to make more informed proposals.

3. Vessel selection – as input: DTOcean does not provide an option for the user to select a vessel as input. The selection of vessels is an output of the tool. For further versions of the tool, it is suggested that vessel selection could be treated as either an input or output.

4. Vessel selection – GUI: The vessel selection is not provided as a result in the GUI, this can only be found if the user explores the code. For future versions of DTOcean, it is suggested that the vessels selected for each activity are identified in the GUI.

5. Equipment selection – DTOcean Library: Update the library to include (smaller) equipment items. An example would be to include the cable reeler, in order to represent projects where cables are laid directly on the seabed.

6. Equipment selection - GUI: The equipment selection is not provided as a result in the GUI. For the improvement future versions of DTOcean, it is suggested that the equipment selected for each activity be identified in the GUI.

7. Main installation tasks: Some onshore preparation activities and offshore activities could run concurrently, however, DTOcean does not consider this. For example, the onshore crew could start the preparation of cables after completing the preparation of foundations.

8. Main installation tasks: DTOcean assumes that all arrays will have a collection point (or subsea hub), but on some sites it may make sense for turbines to have individual cables to shore.

9. Loading rate: DTOcean requires a cable loading rate (m/hour) to be considered. Real array experience suggests that future versions of DTOcean could also provide a second option where the cable is delivered on reels, negating the load rate.

10. Environmental data resolution: The input environmental data needs to be of sufficiently high resolution to make informed assessments of the likely sequence of marine operations.

11. Demobilisation time: DTOcean does not take the demobilisation time into account. This time and associated costs should be considered for the improvement of the tools and accuracy of results.

12. Activities during daylight: Future versions of DTOcean should consider, as an option for the installation module, the limitation of daylight-only activities. Night operations are often avoided due to safety reasons.

13. DTOcean Library: Update vessel costs in the library and expand the range of vessels. E.g. CSV vessels could be up to 10 times more expensive than the options presented.

14. Winter operations: Future versions of DTOcean should consider that activities during winter time can take longer and therefore be more expensive, due to the reduced amount of suitable weather windows and daylight that are available.

15. Decommissioning stage: Decommissioning is not taken into account in DTOcean, this should be added within future versions of DTOcean.

16. Availability: Future versions of DTOcean should include calculations of availability based on downtime of devices and provide more information about the calculation of the array availability.

17. Replacement activity - downtime: The Calendar Based maintenances disregard the downtime of replacement activities. Future versions of DTOcean to revise.

18. LCOE – discounted values: Future versions of DTOcean should revise methods for the calculation of the discounted values of CAPEX, OPEX and AEP, to obtain more realistic values of LCOE.

19. Reliability of the device: Future versions of DTOcean should include the reliability of the device on the RAM.

20. System reliability at mission time: Future versions of DTOcean should include the effects of the O&M in the reliability of the system along its lifetime, as well as, correct initial considerations of the graph, to represent a realistic behaviour.

21. Method of EAM: Future versions of DTOcean should assess the application of the EIS as the environmental assessment, to ensure confidence with this method based on quantitative scores.

22. Functionality of EAM: Future versions of DTOcean should improve the environmental assessment module for the other stages, such as electrical, foundation, installation and O&M.

6 Conclusion and future work

The EnFAIT (Enabling Future Arrays in Tidal) project is demonstrating a grid-connected tidal energy array at a real-world tidal energy site, propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation. Work Package (WP) 10 of the EnFAIT project will seek to validate the open source tool, DTOcean (Design Tool for Ocean Energy Array), and identify improvements for the 2nd generation of the tools (which will be covered in another EU-funded project - DTOceanPlus), based on experience gained during the EnFAIT project.

This deliverable (D10.4) is complementary to D10.3, where the scenario was defined and the first metrics of the tools were assessed and compared with the existing design. Both deliverables complete the capability evaluation of the five (5) modules and three (3) assessments of DTOcean tool. In this deliverable, the Installation and O&M modules as well as the Economic, Reliability and Environmental assessments are investigated.

The initial capabilities and outputs of DTOcean are compared with the existing array, and the classification of similarities is summarised in Table 26. The qualitative analysis presented here highlights differences in the outputs provided by DTOcean and the existing array. In general, the Installation module is classified with a medium level of similarity, as some of the metrics produced by the numerical tool do not compare meaningfully with values from the existing array, such as selection of vessels, departure delay and operation time. The O&M module is classified with a medium level of accuracy and suggestions are made for the improvement of the availability calculation. The weakest module seems to be the economic one, showing discrepancies observed on the calculation of discounted values. At this stage of the project, Reliability and Environmental assessments are classified as Not Applicable. There is a need to refine the model and gain more experience with the existing array before comparisons can be made accurately.

Subsequent deliverables from the EnFAIT project will use this qualitative assessment method of the capabilities of DTOcean to progress to a greater level of validation and refined assessment. Currently, three (3) tidal turbines are deployed in Bluemull Sound, thus this first assessment considered the simulation of three (3) turbines. Later in the project, three more tidal turbines will be deployed in the EnFAIT array and DTOcean outputs will be reassessed. Comparisons with actual designs will also be carried out to evaluate the choices and gain insight from the existing array experience. Finally, when more confidence is gained with the numerical tools, DTOcean will be used to support the extended array design.

7 References

DTOcean. (2016). *DTOcean Technical Manual.*
DTOcean Plus project. (n.d.). *DTOcean Plus [online]*. Retrieved from https://www.dtoceanplus.eu/
DTOcean Project. (n.d.). *DTOcean [online]*. Retrieved 07 25, 2017, from http://www.dtocean.eu
EnFAIT D10.2. (2018). *Bluemull Sound Site Resource Map.*
EnFAIT D10.3. (2018). *DTOcean - Scenario Definition Performance Metrics v1.4.*

Appendix I

The following list provides a high-level summary of the different recommendations made in this report and lists the pages that each can be found on.

Recommendation 1: Remove limitation on number of ports that can be selected.................................. 16
Recommendation 2: Improve the vessel selection function to make more informed decisions 17
Recommendation 3: Permit vessels to be manually selected... 17
Recommendation 4: Include vessel selection on the Graphical User Interface....................................... 17
Recommendation 5: Update library to include additional + smaller equipment items............................ 18
Recommendation 6: Include equipment selection on Graphical User Interface...................................... 18
Recommendation 7: Permit activities to run concurrently when appropriate... 18
Recommendation 8: Allow for turbines to have individual cables (where appropriate).......................... 18
Recommendation 9: Provide option for pre-loaded cables... 19
Recommendation 10: Ensure environmental data is of sufficiently high resolution to make meaningful assessments.. 20
Recommendation 11: Demobilisation time to be included 21
Recommendation 12: Limit night operations.. 21
Recommendation 13: Expand range of vessels in DTOcean library and update costs 22
Recommendation 14: Incorporate seasonal activities... 22
Recommendation 15: Decommissioning.. 22
Recommendation 16: Develop the availability calculations and outputs 23
Recommendation 17: Consider the downtime of replacement activity... 24
Recommendation 18: Improve calculation methods for discounted CAPEX/OPEX/AEP values to obtain realistic values of LCOE... 25
Recommendation 19: Include device reliability.. 26
Recommendation 20: Include O&M in reliability of the system.. 27
Recommendation 21: Ensure confidence with the EIS method.. 28
Recommendation 22: Apply EAM to different stages.. 29

EnFAIT

Contact

HEAD OFFICE

Nova Innovation
45 Timber Bush
Edinburgh
EH6 6QH

Tel: +44 (0)131 241 2000
Email: info@enfait.eu

www.enfait.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 745862.